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PERFORMANCE TESTING INSTRUMENTS FOR AIRPLANES

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The following publication, entitled "Performance Testing Instruments for Airplanes," is published for the information and guidance of all concerned.

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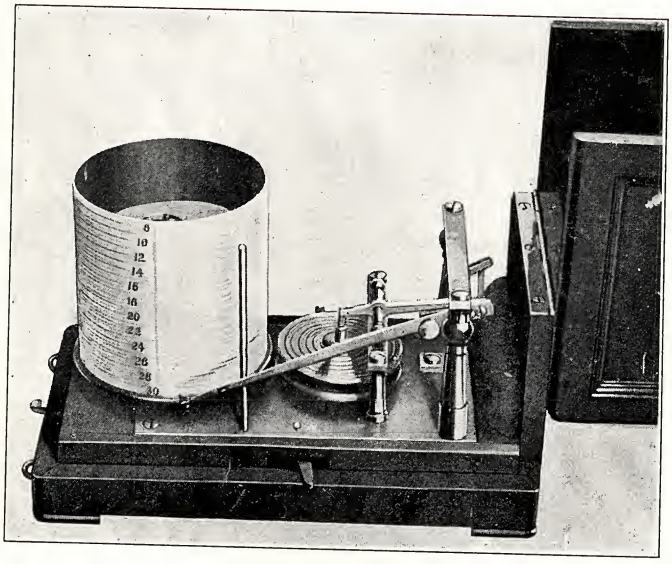


FIG. I.—ALTIGRAPH.

INSTRUMENTS FOR PERFORMANCE TESTING.

For performance testing special instruments are required, many of which are of a recording type, that a continuous record may be made without the attention of the pilot or observer. These will be described in this pamphlet, but the reader is referred to "Practical Airplane Performance Testing" for a discussion of the use of the instruments and methods of reducing the readings to standard conditions.

1. Altigraph.

This instrument is a recording altimeter, and is a modification of the aneroid barograph used by the weather stations for recording atmospheric pressure changes. An altigraph manufactured by Julius Richard, Paris, and one of the most satisfactory in use, is shown in Figure I. An instrument of similar design is made by Henry J. Green, Brooklyn. Two aneroid boxes are used in place of the single one of the altimeters, which give a larger movement of the aneroid pillar. The motion of this pillar is transmitted by a compound lever to a horizontal shaft on which is mounted a long pointer. This carries at its outer end a pen which traces a curve on the specially ruled chart on the drum. The drum is driven by a clock inside. For ordinary performance tests a drum making one turn in an hour is most satisfactory, but for tests with a fast-climbing airplane an half-hour drum is to be preferred, while for endurance tests, or cross-country flying, a six or eight hour drum may be desirable. The drum turns in a clockwise direction (as one looks down on it), so the chart should be placed on it with the right edge covering the left. Then on a flight longer than the period of the drum the lap will move readily under the pen without catching. The lower edge of the chart should rest evenly on the flange of the drum all the way around, and the drum set so that at the start of the flight the pen is just at the right of the lap.

An altigraph of a range of 8,500 meters (28,000 feet) is the type most often used by the Flight Testing Department of the Engineering Division.

The satisfactory operation of the altigraph, or any recording instrument, requires a type of mounting in the airplane which will

eliminate vibration. This may be accomplished by suspending on rubber cords. But care should be taken that this is done in such a way that no torsional oscillation will occur.

2. Air Speed Recorder.

An air speed indicator of the type described in "Air Speed Meters for Aerial Navigation," is a very important instrument to guide the test pilot in holding a ship to a constant air speed, in maintaining a constant level, and in judging the best rate of climb. But an air speed recorder is necessary for a complete record of the test. The Toussaint-Lepere recording air speed meter is the instrument used. The pressure head is a Venturi-Pitot tube very similar to the pressure head of the standard air speed meter. This is mounted on a spar fastened to the interplane struts so as to be several feet in front of the leading edges of the wings. This practice is followed so that the pressure head will be in air undisturbed in flow by the airplane. The recorder is shown in Figure II. The pen arm *b* is actuated by two bellows *c*, the upper of which is connected to the Venturi and the lower to the Pitot of the pressure head. A rod *d* connects the movable plates of the bellows, and is moved vertically up with increasing air speed, due to the suction of the Venturi on the upper bellows and the pressure of the Pitot on the lower. The motion of *d* is communicated to *b* and magnified by a lever system. The weight *e* is a balance for the moving parts.

The recording part of this instrument, consisting of a clock-driven drum carrying a chart, is very similar to that of the altigraph. The chart is specially ruled to indicate the air speed in miles per hour. This air-speed meter must be calibrated for each installation by flying over a measured course.

3. Statoscope.

The purpose of this instrument is to enable the pilot to hold the airplane at a constant level. It may be considered to be a sensitive altimeter, or rather an altiscope, which indicates a small change of altitude. Such an instrument may be constructed from a small thermos bottle. A two-holed rubber stopper closes the mouth, with a small U-tube manometer placed in one hole, and a piece of tubing ending in some kind of a valve or pinch cock in the other. The manometer is partly filled with a liquid. The other tube is left open until the altitude is reached at which it is desired to fly level. The valve then is closed. The bottle now contains a mass of air at a pressure corresponding to the desired altitude. If the airplane ascends,

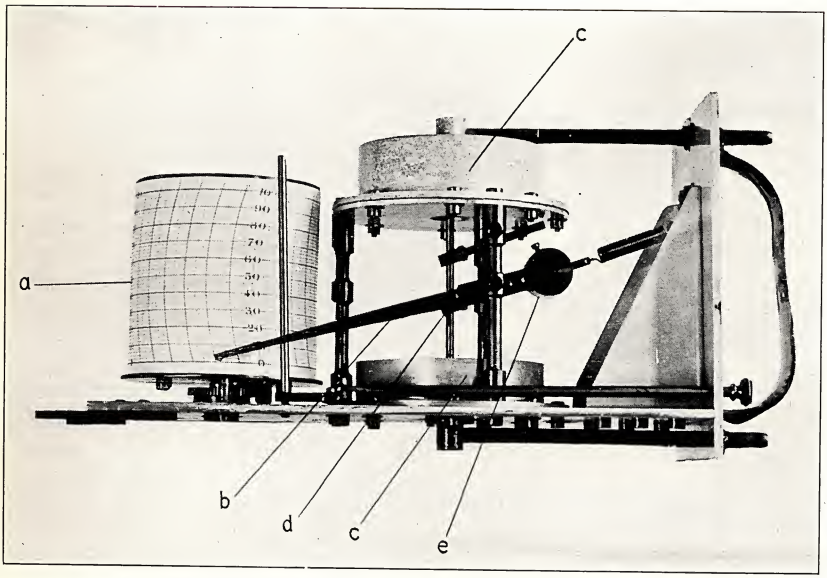
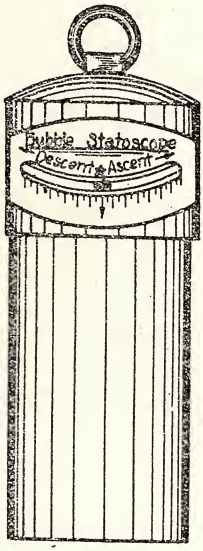
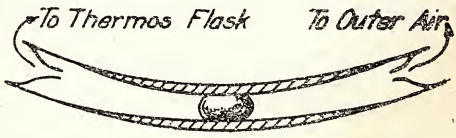


FIG. II.—TOUSSAINT-LEPERE AIR-SPEED RECORDER.

the pressure in the bottle is greater than outside and the liquid in the outer arm of the manometer rises; if the airplane descends the pressure inside is less than outside and the liquid falls. The object of using a thermos bottle is to have a container which will insulate the air from temperature changes. While a thermos bottle comes the nearest of fulfilling this requirement it is not perfect, and on long flights there is an error due to temperature change.

Figure III shows an improved form of statoscope, known as the "Bubble statoscope." The air reservoir is a thermos bottle, as above, but the manometer is replaced by a curved capillary tube containing a drop of some liquid, which forms the so-called "bubble." This





Glass gauge and traps used on Bubble Statoscope

FIG. III.—Bubble Statoscope.

liquid should have a low vapor pressure, and its viscosity should not be excessive at low temperatures. At each end of the tube there is an enlargement of the bore which acts as a trap, so when the bubble is pushed to one end it breaks and reforms without loss of any of the liquid. On ascending the bubble moves toward the outer end, and on descending toward the reservoir end. This type of statoscope is an improvement over the former in that the pilot does not have to open a valve on making any large change in altitude. For, on ascending, when the bubble reaches the outer end, the capillary is opened so some air escapes, and on leveling off, the bubble reforms and closes the tube. On descending, a similar process occurs at the opposite end with the difference that air is left in the reservoir.

A "mechanical" type of statoscope has been used to some extent. In this form the reservoir is an aneroid box and its motion is transmitted to a pointer and magnified by a lever system. This type is not as well insulated against temperature changes as the type with the thermos bottle reservoir.

Statoscopes have been used considerably in flight testing, but are not altogether satisfactory. A pilot must learn to watch the instrument and change his controls according to the indications. Pilots are able to keep a given level better by watching the air speed indicator and altimeter. By a few trials an air speed is found which keeps the airplane at a constant altitude, and this can be maintained easily in quiet air.

4. Clinometers, or Rate of Climb Meters.

Any of the three types of statoscopes described in paragraph 3 may be modified so as to indicate *rate of climb*. Such an instrument will enable a pilot to find the conditions of maximum rate of climb of a new airplane more quickly than otherwise, and also make possible duplication of rate of climb tests by different pilots.

The valve of the first type, using a thermos bottle and U manometer, may be replaced by a capillary tube. On ascending, air leaks out through the capillary tube, the rate of leak being proportional to the pressure difference, and this pressure difference being proportional to the rate of ascent, if one assumes that the change in external pressure is directly proportional to the change in altitude. Of course this assumption is not true and only holds approximately for a limited range. Calibration for one altitude will not hold for another. Such an instrument can be calibrated by comparing the reading of the manometer with the rate of climb determined from altimeter and stop-watch readings. However, since the instrument is intended as a guide for the pilot in finding the conditions of maximum rate of climb, rather than an instrument for measuring the actual rate of climb, the calibration is not an important factor. It is found convenient to make the scale correct for a mean altitude, say 8,000 to 10,000 feet.

Figure IV shows diagrammatically a very well designed form of such a rate-of-climb meter used by the testing squadrons, British Royal Flying Corps.

The bubble statoscope may be used as a rate-of-climb meter without any modifications. The number of times per minute that the bubble breaks is a measure of the rate of climb. Such an instrument can be calibrated to give the actual rate of climb by determining the change in altitude which causes the bubble to break once.

The aneroid or mechanical statoscope can be made into a rate-of-climb meter by connecting the aneroid to the external pressure by a capillary tube, as with the thermos bottle manometer.

5. Thermometer.

No performance-testing data is complete without the atmospheric temperatures throughout the range of altitude of the test. The

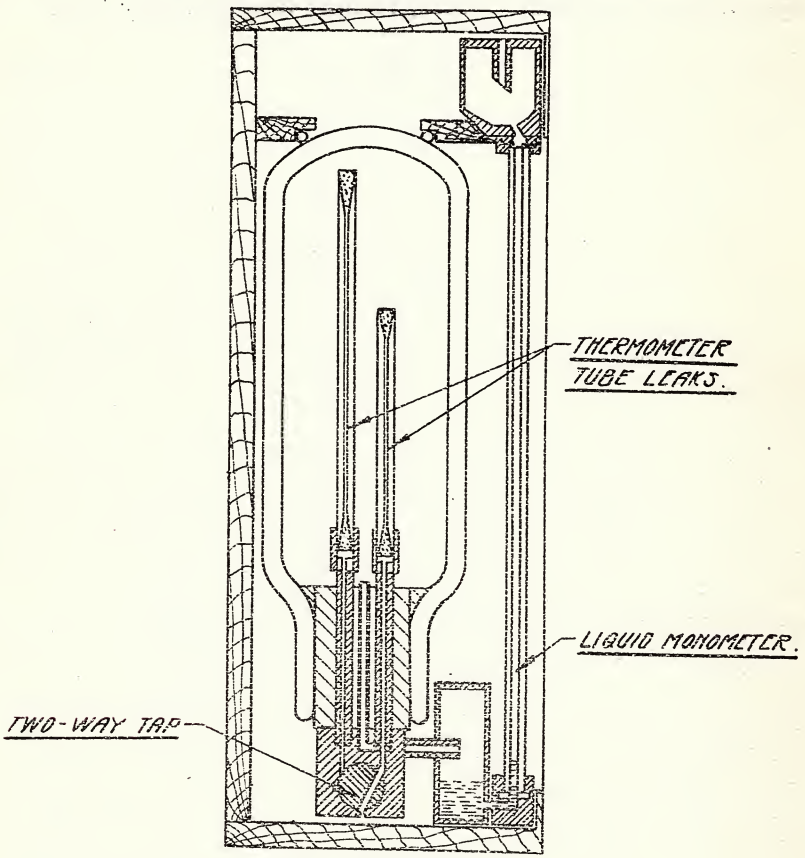


Fig. IV.—Rate of Climb Meter.

most satisfactory method of obtaining these is by a strut thermometer of the liquid-in-glass type. Such a thermometer should have the following characteristics: (1) An open scale, with figures large enough to be read at a distance of 20 feet; (2) a large bore, so the top of the liquid column can be easily seen; and a large bulb, shielded by a cellular metal casing, which will keep off the sun's rays, but allow free circulation of the air. A very good thermom-

eter, fulfilling these requirements, is made by J. J. Hicks, London, and the Taylor Instrument Co., Rochester, N. Y.

A recording thermometer is highly desirable, but so far none have been produced satisfactory for airplanes. The same type of thermometer as used for radiator thermometers, but with a smaller range in the scale, have been used as strut thermometers. This form has the *advantage* of bringing the scale close to the observer, but the disadvantage of being subject to greater errors, due to the effect of the temperature of the communicating capillary tube.

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